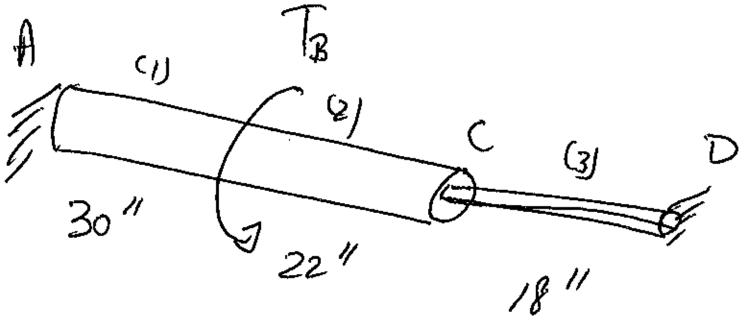


Find $T_{B\,\text{MAX}}$

$d_1 = d_2 = 3.5$ in

$t_w = 0.12$ in

$G_1 = G_2 = 12.5 \times 10^3$ ksi

$\tau_{ALLOW} = 50$ ksi

$d_3 = 2$ in (solid)

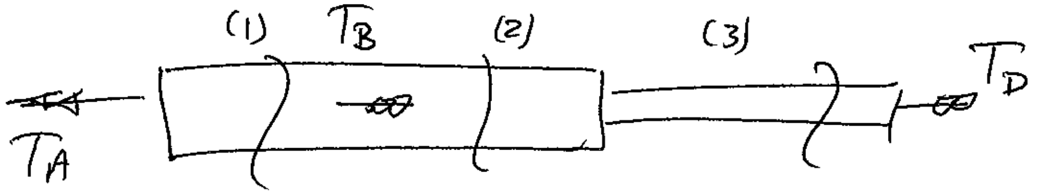
$G_3 = 5.6 \times 10^3$ ksi

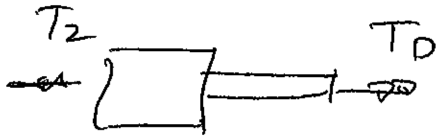
$\tau_{ALLOW} = 18$ ksi

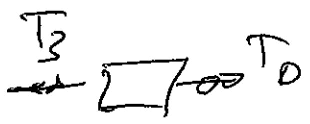
Materials in series:

$$\phi_1 + \phi_2 + \phi_3 = 0$$

$$\frac{T_1 L_1}{I_{p1} G_1} + \frac{T_2 L_2}{I_{p2} G_2} + \frac{T_3 L_3}{I_{p3} G_3} = 0 \qquad ①$$







$T_1 = T_A$ $\qquad T_2 = T_D$ $\qquad T_3 = T_D$ ②

$\overrightarrow{\Sigma T} \qquad -T_A + T_B + T_D = 0$ ③

$T_A = T_B + T_D$

Combine ①, ②, & ③

$$\frac{T_A L_1}{I_{P1} G_1} + \frac{T_D L_2}{I_{P2} G_2} + \frac{T_D L_3}{I_{P3} G_3} = 0$$

$$\frac{(T_B + T_D) L_1}{I_{P1} G_1} + \frac{T_D L_2}{I_{P2} G_2} + \frac{T_D L_3}{I_{P3} G_3} = 0$$

Algebra to solve for T_B

$$(T_B + T_D) + T_D \frac{L_2}{L_1} \frac{I_{P1}}{I_{P2}} \frac{G_1}{G_2} + T_D \frac{L_3}{L_1} \frac{I_{P1}}{I_{P3}} \frac{G_1}{G_3} = 0$$

$$T_B = -T_D \underbrace{\left(1 + \frac{L_2}{L_1} \frac{I_{P1}}{I_{P2}} \frac{G_1}{G_2} + \frac{L_3}{L_1} \frac{I_{P1}}{I_{P3}} \frac{G_1}{G_3} \right)}_{\text{call this } \alpha}$$

in terms of T_A:

$$T_B = -(T_A - T_B) \left(\quad \alpha \quad \right)$$

$$T_B = (-T_A + T_B)\alpha$$

$$T_B = -T_A\alpha + T_B\alpha \qquad T_B - T_B\alpha = -T_A\alpha$$

$$T_B(1-\alpha) = -T_A\alpha$$

$$T_B = -T_A \frac{\alpha}{1-\alpha}$$

$$\alpha = 1 + \frac{22}{30}\,\overset{=1}{\cancel{\frac{I_p}{I_{p2}}}}\,\overset{=1}{\cancel{\frac{G}{G_2}}} + \frac{18}{30}\,\frac{\cancel{\pi/32}\,[3.5^4 - 3.26^4]}{\cancel{\pi/32}\,[(2)]^4}\,\frac{12.5}{\cancel{28}5.6}$$

$$\alpha = 4.84$$

Assume each section is critical, find corresponing internal Torque. Note that these values are independent (do not happen together).

$$\tau = \frac{T\, d/2}{I_p}$$

$$d_i = 3.5 - 2(0.12) = 3.26$$

① $$50 \times 10^3 = \frac{T_1 \frac{3.5}{2}}{\frac{\pi}{32}\left[3.5^4 - 3.26^4\right]}$$ $T_1 = 104.1$ kip·in

$T_1 = T_A$ $$T_B = \frac{(-104.1)(4.84)}{1-4.84} = \underline{131.2 \text{ kip·in}}$$

---

② $$50 \times 10^3 = \frac{T_2 \frac{3.5}{2}}{\pi/32\left[3.5^4 - 3.26^4\right]}$$ $T_2 = 104.1$ kip·in

$T_2 = T_D$

$T_B = -T_D \cdot \alpha$ $\underline{T_B = 503.9 \text{ kip·in}}$

---

③ $$18 \times 10^3 = \frac{T_3 \; 2/2}{\pi/32 \; 2^4}$$ $T_3 = 28.27$ kip·in

$T_D = T_3$

$T_B = -T_D \cdot \alpha$ $\underline{T_B = 136.8 \text{ kip·in}}$

T_B = Minimum of these

$T_B = 131.2$ kip in